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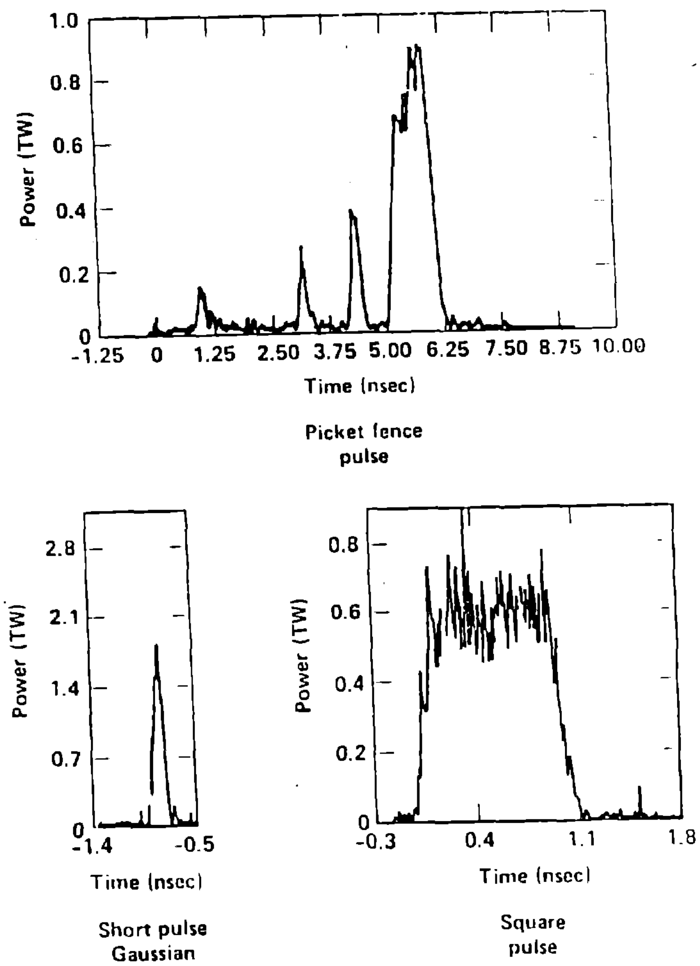
The Nova laser facility is designed to address critical issues for evaluating the feasibility of Inertial Confinement Fusion, to implode DT to densities exceeding 200 g/cm^3, and to perform a wide range of high energy density plasmas physics experiments in the areas of XUV/x-ray lasers, hydrodynamics, and radiation generation and transport. The ten-arm Nova laser is capable of irradiating complex targets with laser wavelengths of 0.53 and 0.35 μm, pulse widths from 0.09 ns to > 5 ns, peak powers greater than several terawatts per beam line, and temporally shaped pulses. The output of the laser can be directed into two independent target areas; a 4.6 m diameter vacuum vessel for experiments which require ten beams and a 1.8 m diameter chamber for two Nova arms. A number of sophisticated optical, XUV, x-ray and particle diagnostics measure target performance. An overview of the facility will be presented and recent target experiments will be discussed. These target experiments include studies of forward stimulated Raman scattering and hot electron production, ablation pressure, XUV lasers, x-ray conversion efficiencies and implosions.

Laser Facility

Nova is a versatile facility with capabilities that allow a wide range of experiments to be performed. Laser wavelengths of 1.06, 0.53, and 0.35 μm are available in temporally shaped pulses with pulse widths from 0.08 to 100 ns. Complex temporal shapes such as square pulses or "picket fences" have been obtained and are in routine use (see Fig. 1).

Two chambers are used for target experiments. The ten beam chamber is 4.6 m in diameter and can be used to irradiate a target with all ten Nova arms at 0.53 or 0.35 μm wavelength. Spot sizes down to 100 μm in diameter can be achieved with a pointing and target positioning accuracy of 50 μm. A 1.8



1. Examples of Nova output pulse shape at 0.35 μm.

diameter chamber is also used for experiments requiring only two Nova beams. Cylindrical lenses on this chamber can also produce a line focus 100 μm wide up to 5 cm long.

Target Diagnostics

A wide range of target diagnostics are available on the Nova target chambers. Optical diagnostics include a pin diode array, spectrograph streak cameras, a Cassegrain telescope streak camera, and a 100 ps framing camera. XUV/x-ray diagnostics include grazing incidence spectrometers, a transmission grating

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cameras, streak cameras, and 8x Kirkpatrick-Baez microscopes. For high energy x-rays (ten to a few hundred keV) there are a multi-channel filter fluorescer x-ray spectrometer and zone plate cameras. All optical and x-ray streak cameras have an absolute timing fiducial. Particle diagnostics include copper activation for neutron yield, neutron time-of-flight for ion temperature, and neutron activation for compression measurements.

Advanced diagnostics under development include a two-dimensional x-ray framing camera with 50 ps frames, a high energy x-ray microscope (up to 15 keV) using multilayer mirrors, a neutron spectroscopy system, neutron imaging capability, and time-resolved neutron measurements ($\Delta t < 20$ ps).

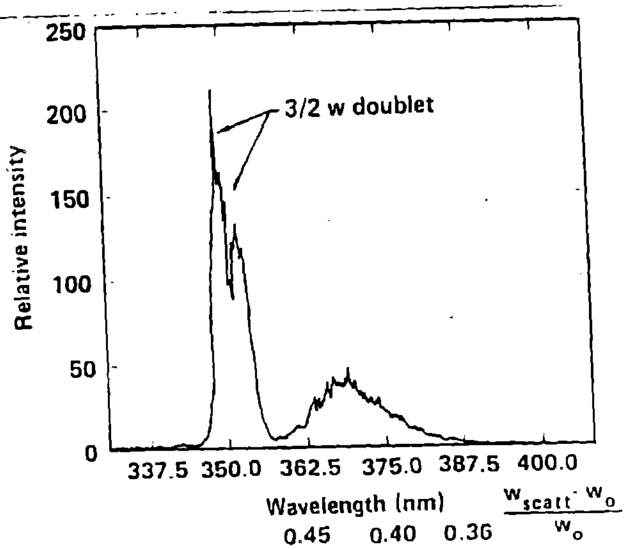
Nova Target Experiments

Several target physics experimental series have already began at Nova. Initial results include measurements in the areas of forward stimulated Raman scattering and hot electron production, ablation pressure, XUV lasers, x-ray conversion efficiencies and implosions.

Forward Stimulated Raman Scattering (SRS)

Forward SRS produces high phase velocity electron plasma waves which can produce very fast electrons. These electrons can preheat the fuel in an ICF implosion. Experiments at Nova have studied the relationship of forward SRS and hot electron production and determined the forward SRS threshold.

These experiments involve using 0.53 μm wavelength light to irradiate a thin target which quickly becomes underdense. Forward scattered SRS light is observed with streaked spectrometers (see Fig. 2) and correlated to



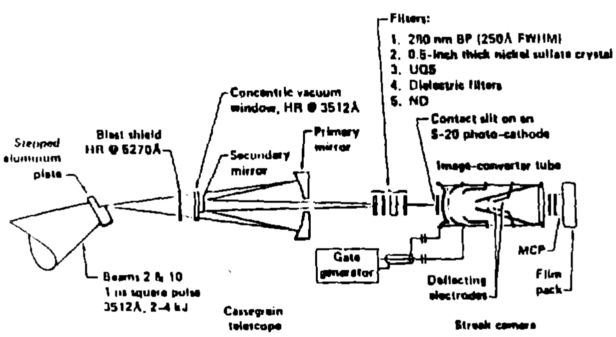
2. Forward SRS; upshifted spectrum near middle of laser pulse obtained with a streaked optical spectrometer.

filter fluorescer measurements of the high energy x-rays produced by hot electrons. "Superhot" ($T > 100$ keV) tails on the x-ray spectra have been observed, which agree well with electron energies corresponding to the phase velocity of the electron plasma wave as inferred from the forward SRS light wavelength.

The conclusion of these experiments is that SRS is a major source of the hot electrons observed with forward SRS producing the superhot component. Strong threshold behavior near 2×10^{15} W/cm^2 for forward SRS has been observed.

Ablation Pressure

0.35 μm, 1 ns square pulses have been used to irradiate a stepped aluminum plate; a Cassegrain telescope - streak camera, is used to observe the shock wave break-out on the back side of the target (see Fig. 3). The time difference between the shock break-outs in the stepped regions can be related to the ablation

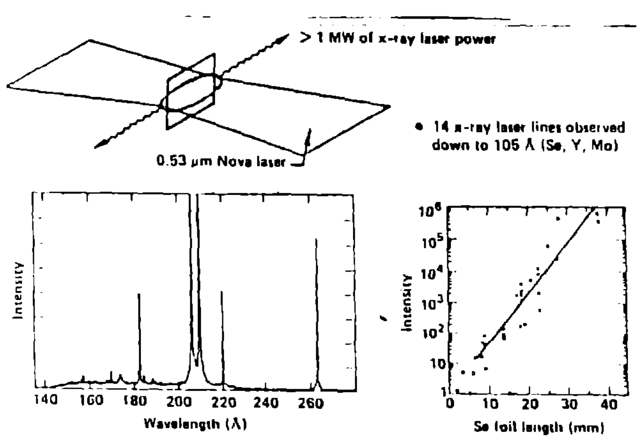


3. Experimental set-up for determination of ablation pressure from measurement of shock velocity.

pressure driving the shock. Preliminary shock pressures in excess of 100 Mb have been achieved with scaling of pressure as a function of laser intensity agreeing well with theoretical models.

XUV Lasers

The Nova two beam chamber has been used in experiments to develop short wavelength lasers. Two beams of 0.53 μm light totaling up to 5.0 kJ have been used in a line focus of lengths up to 5 cm to irradiate "exploding foil" XUV laser amplifiers (see Fig. 4). Neon



4. Nova experiments have used "exploding foils" to produce XUV lasing. X-ray laser gain has been observed to scale exponentially with amplifier length.

like Se, Y and Mo have produced lasing lines as short as 106 Å (Mo) and Se amplifiers have achieved output powers of over 1 MW. Exponential scaling of XUV laser beam intensity with amplifier length has been observed, and gain coefficients for several of the lasing lines have been measured.

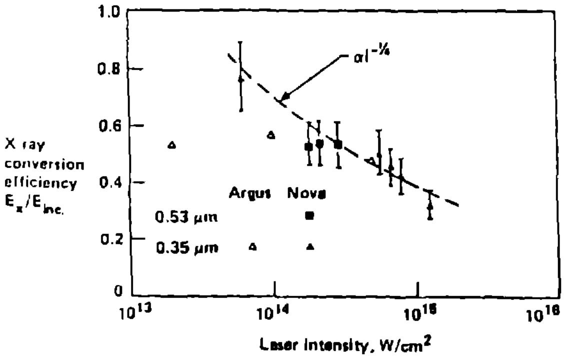
Current goals are to improve the output power by understanding and controlling refraction effects which are limiting amplification and to attempt to reach shorter wavelengths (60-80 Å) through the use of higher Z, Ne-, Ni-, and H-like ion inversion schemes.

X-Ray Conversion Efficiency

X-ray driven targets require that laser light be converted to soft x-rays. High conversion efficiencies for this process are required for optimum use of the laser energy. Experiments at Nova using 0.53 and 0.35 μm light to irradiate gold disks show high absorption efficiencies (>80% for 0.35 μm and > 70% for 0.53 μm) for intensities from 4×10^{13} W/cm^2 to < 4×10^{15} W/cm^2. This result is independent of laser angle of incidence up to the largest angles, (47°) measured in these experiments. X-ray conversion efficiency was observed to scale approximately as $I^{-1/4}$ where I is laser intensity (see Fig. 5). Total conversion efficiencies (E_x/E_{inc}) up to 75%, were achieved with 0.35 μm light.

Implosions

Both electron (direct) driven and x-ray (indirect) driven implosions of DT targets have been done using ~20 kJ of 0.35 μm light in the ten beam chamber. The direct drive targets (glass micro-balloons with nominal dimensions of 1000 μm x 2 μm and DT pressures of



5. X-ray conversion efficiencies measured at Nova.

12-14 atm) produced neutron yields in excess of 10^{13} and fusion efficiencies > 0.15%. Implosion characteristics were low fuel areal density (<1 mg/cm^2) and high ion temperatures (>10 keV) as measured by neutron time-of-flight. Indirect drive targets achieved higher compressions (areal density estimated > 10 mg/cm^2) with neutron yields of 3-5 x 10^{10} and ion temperatures of 1.7 ± 0.3 keV.

Conclusion

The Nova laser is an operating facility with the versatility in both laser conditions obtainable, and target diagnostics available to allow a broad range of research into the physics of high energy density plasmas. Initial experiments have already produced data addressing several of the issues related to achieving high gain ICF implosions. Developmen on advanced diagnostics is continually increasing the facilities' capabilities.